THE STATE OF WEIGHTLESSNESS AND PROTECTIVE MEASURES

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16. Abstract

Past experience indicates that human stay in weightlessness during space flight induces some changes in the astronaut's organism. These changes become especially noticeable after return to earth gravity conditions. However, these changes are reversible. In order to prevent the deconditioning of the organism in zero gravity, certain countermeasures are taken. Certain protective techniques can be used to facilitate the readaptation of the human body after landing on earth.

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THE STATE OF WEIGHTLESSNESS AND PROTECTIVE MEASURES

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When sending a man into cosmic space his organism is exposed to a series of stress factors, such as acceleration, deceleration, noise, vibrations, confinement in the tight cabin space of the space ship and weightless state. The question of the effect of the weightless state on the human organism is of primary importance for space medicine and biology, and even more so because the remaining stress factors of space flight can be successfully simulated under earth's conditions for their intensity and duration, which is not the case for a state of weightlessness. /44*

Several scores of cosmonauts have participated in past space flights, and have spent several thousands of hours in the weightless state. It was observed, either through direct measurements during the flight itself or after return to earth that certain changes had occurred in the cosmonaut's organism, in the cardiovascular and bone-muscle system, loss of body weight, and changes in the microflora and vestibular apparatus. The return to earth conditions is accompanied with an increase in body weight, reduction in work capacity, weakened body support in vertical position, change in the manner of walking, loss in calcium and potassium, and other changes. All of these observed changes were of a temporary character, as after a certain time interval the organism would return to the same state as before the flight into space.

The question is if the observed changes in weightless

*Numbers in the margin indicate pagination in the foreign text.

state are components of the organism's adaptation to that state and would they stop when a certain level is reached, or are they progressive and would become more and more pronounced with the cosmonaut's increased stay in space. If the latter condition proves to be correct, the length of man's presence in space would be severely curtailed if there were no countermeasures that would prevent these changes. The knowledge acquired so far on the effect of the weightless state on various organs and systems, on the metabolic and biochemical changes in cells is insufficient and, therefore, the answers to these /45
questions will come from research and tests to be performed in space orbital stations in which men will stay much longer than in past orbital and translunar flights. One should expect that the effects of weightless state on the human organism under conditions of long flights will be researched in more detail. This broader scope research will include the cardiovascular and respiratory systems, the vestibular and locomotive apparatus, the digestive apparatus, the thermal regulating system, the system of the state of wakefulness and sleep, as well as the functions of the central and peripheral nervous system.

The state of weightlessness is a non-physiological state for man, as his organism as well as that of all other living creatures on our planet, was developing and adapting, functionally and anatomically, to the gravity force. This is the reason why one should expect certain physiological, physiopathological and biochemical changes in the organism of live creatures under conditions of weightlessness. Gravity, inertia, and external forces act on the human organism under earth's conditions. In conformity to the theory of relativity the gravity and inertia forces have an action field and therefore their effect is spread uniformly over all body molecules. Man feels the action of the power field through his senses only under conditions of the ambient that causes a certain deformation of the body structure, when there is interaction between the body and the

support. Such a field of the power field effect is weight. Outside forces do not have a power field as they act only on the surface of the body and the location of their effect is localized. In weightlessness, there is a balancing of gravity and centrifugal forces, an absence of interaction between the body and the support, and all of these results in the G loading becoming zero, and this is the state of weightlessness (Fig. 1).

In this article certain physiological changes that were observed during past space flights will be presented briefly, and certain protective measures that could be successfully applied in the struggle against these changes will be pointed out. Observations have shown that not a single change in the /46 cosmonaut's organism, determined after the flight, was of such a magnitude that it remained irreversible. Certain physiological changes were observed, primarily in the cario-vascular system, skeleto-muscular system, as well as certain endocrinal electrolytic changes.

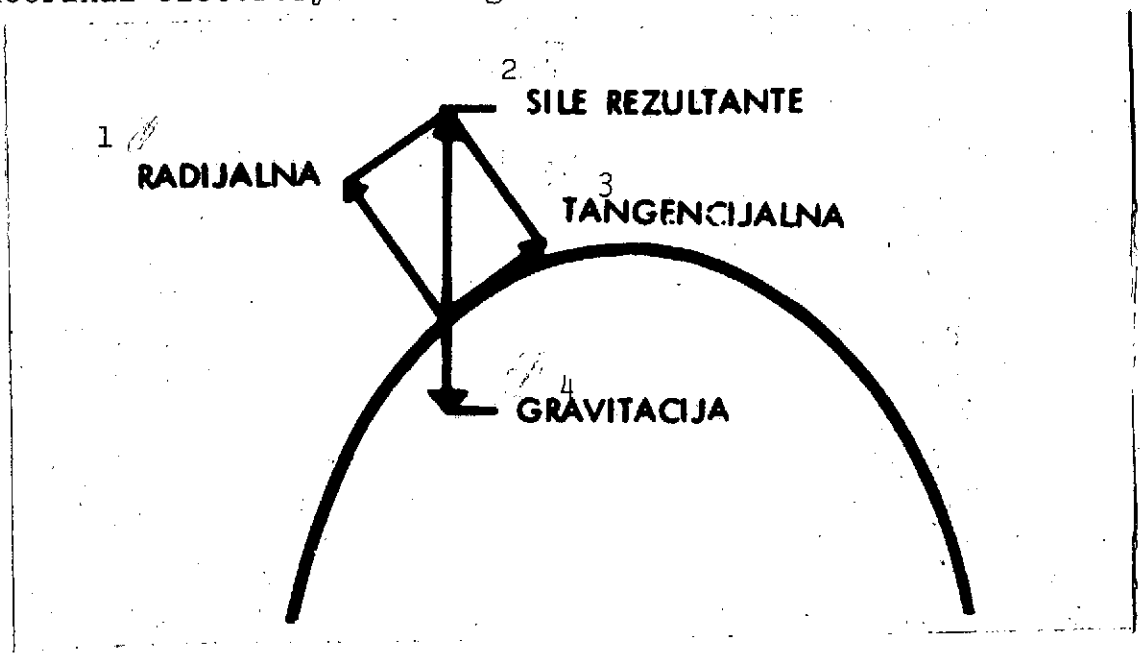

Fig. 1. Forces acting in orbital flights that create conditions of weightlessness.

Key: 1. Radial, 2. Resulting force, 3. Tangential, 4. Gravity

Cardiovascular Reactions

The behavior of the cosmonaut's cardiovascular system was examined extensively as this was the system that reacted most dramatically to space flight conditions. The following changes were observed:

Heart rhythm	--	Stabilized at a lower level under zero gravity.
Electrical activity	--	Normal, with occasional appearance of bigeminy and extra systole
Heart profile	--	Reduced after flight.
Tolerance to orthostatic tests/standing and tilt table	--	Reduced after flight.

During continued weightlessness, there is a lack of blood hydrostatic pressure against which the heart must work when gravity is present, which is why the heart in the weightless state works only to overcome the force of friction resulting from the movement of blood in the blood vessels. As a consequence of peripheral resistance in the form of hydrostatic pressures, heart deconditioning occurs: the heart function is slower, the systolic volume is reduced, the work capacity of the heart muscle and the dimensions of the heart itself are reduced. This deconditioning of the cardiovascular system becomes more pronounced after return to gravity conditions, as established physical loading and orthostatic tests (Fig. 2 and Table 1). /47

Changes in the Skeleto-Muscular System

Bone rarefaction has been established by X-rays. The cause of this is not quite clear, but it can be linked to hypodynamics and the removal of calcium from the bones in order to correct the electrolytic imbalance in weightlessness.

Due to inactivity of the muscles, they atrophy and increased nitrogen loss occurs. Pain is felt in the muscles, and locomotive activity is affected.

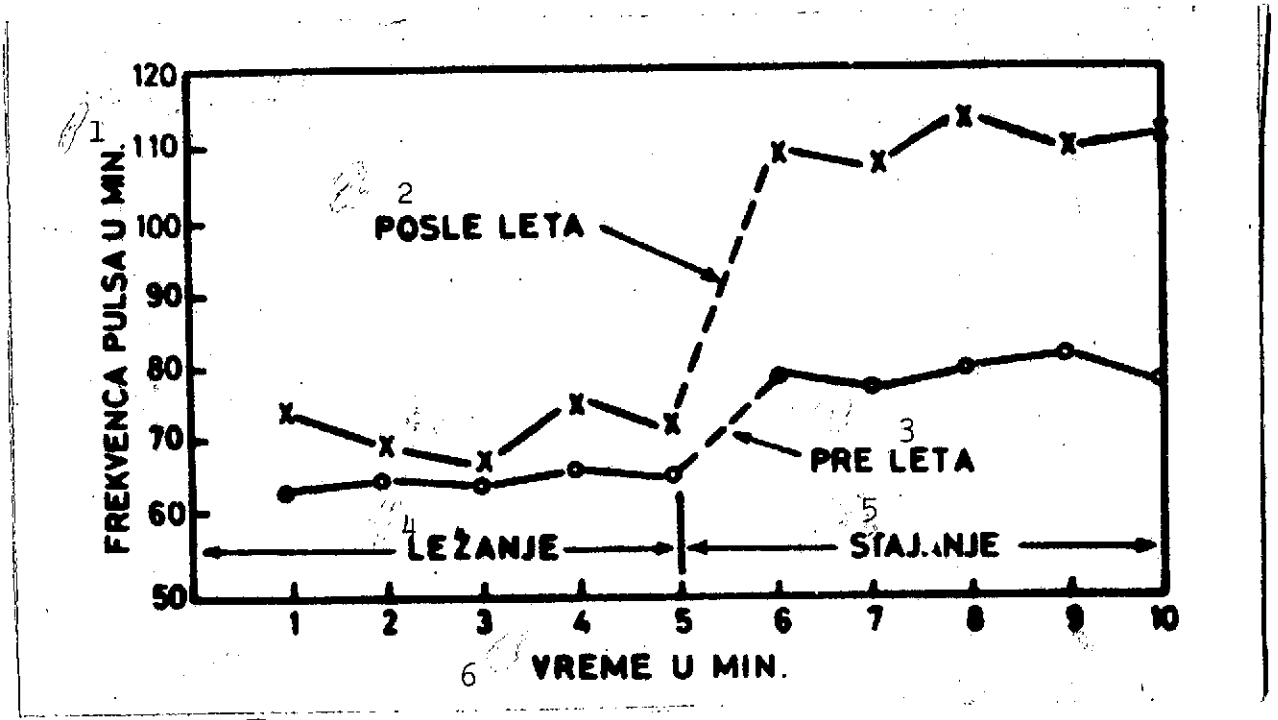

Fig. 2. Pulse frequency and orthostatic tests

Key: 1. Pulse frequence, in minutes
2. After flight
3. Before flight
4. Lying down
5. Standing
6. Time in minutes

TABLE 1. RELATION BETWEEN PULSE FREQUENCY AND PHYSICAL LOADING /48

Pulse Frequency	Before Flight	After Flight
120	80 Watts	25 Watts
140	120 Watts	70 Watts
160	140 Watts	115 Watts

Loss of Body Weight

During space flight there is a loss of body weight of 1 to 6 kilograms. This lost weight is regained in a very short time after space flight. It is felt that the loss of weight

primarily results from the loss of intracellular liquid, as confirmed by biochemical analysis. The process of redistribution of liquid in the organism during adaptation to zero gravity can be shown in the following manner: /49

The experience of zero gravity → The organism attempts to reduce brings about a redistribution the volume of circulating liquid of the blood in circulation by reducing the excretion of the ADH (Antidiuretic Hormone) and aldosterone

↙

Losses of water (diuresis), → Plasma volume is reduced natrium and potassium occur, leading to the loss of body weight

↙

Excretion of ADH and other aldosterones is increased, → The loss of body weight stops. nitrium excretion is introduced, A new balance is established and through increased lung between body liquid and electrolytes. ventilation, the CO_2 in the plasma is reduced.

This represents the hypothetical progression of the organism's adaptation to weightlessness with respect to the loss of body weight that has been noted in man's past experience under conditions of weightlessness during space flight. It is possible that a man's longer presence in space would necessarily result in the establishment of a new physiological state with a new blood circulation volume and its corresponding water-electrolyte balance -- a sign of successful adaptation rather than continuation of a process that would lead to a negative electrolytic balance; that is, a process that would inhibit adaptation to weightlessness. However, since it is presently impossible to state with certainty whether positive

adaptation to longer periods of weightlessness will develop, and what period of time will be required for such adaptation, /50 specific preventive, protective measures will have to be taken in order to prevent deconditioning of the organism under zero gravity conditions, so as to assure that readjustment to gravity conditions is as safe and painless as possible.

Protective Measures

To reduce the deconditioning processes to a minimum under conditions of weightlessness, many preventive measures are planned, the application of which should enable the return of man to gravity conditions with the least amount of pain. These measures are primarily directed at the protection of the cardiovascular and skeleto-muscular system.

Cardiovascular System

Under zero gravity conditions the heart muscle has adapted its function to the absence of blood hydrostatic pressure. However, this adaptation brings many discomforts to the cosmonauts upon return to earth. Thus, under the renewel effect of gravity, blood flows to the legs and consequently appreciably worsens the supply of blood to the brain, and does not assure the necessary return of venous blood to the heart. Under renewed gravity conditions, the heart is exposed to a new load to which it is no longer adapted, resulting in accelerated heart action and even collapse.

There are several different ways to compensate for the effects of the drop in blood hydrostatic pressure during weightlessness. These are primarily the application of a negative pressure of -30 to -70 mm Hg on the lower part of the body, breathing under overpressure, and the use of anti-G suits. The usefulness and effectiveness of these methods were proven on persons who have spent a long time in bed or who were submerged in water (simulated laboratory weightless-

ness), since these conditions bring about reactions which are similar to those after return from a weightless state when such persons are exposed to physical loadings or are placed in a vertical position. The results obtained have demonstrated that the application of the above methods was useful, since /51 the consequent disturbances of the cardiovascular system were much smaller.

Skeleto-Muscular System

To prevent the consequences of the absence of weight loads on the skeleto-muscular system in weightlessness, loadings that simulate the effect of gravity are provided. It is planned that cosmonauts under weightlessness will perform motions similar to walking, running, and weight lifting. To carry out these exercises, elastic springs, an ergocycle and an electrically-driven movable track in a vertical position will be used. This equipment was tested in laboratory-simulated weightlessness and has shown positive results. Physical work, that is, exercises during flight, should conserve the fliers' physical condition and prevent skeleto-muscular disturbances. In addition to these exercises, supplements of calcium, phosphate and potassium will be consumed in order to reduce the mineral imbalance.

Physical training, negative pressure on the lower part of the body, respiration under overpressure and anti-G suits have had a positive, preventive effect in counteracting deconditioning of the cardiovascular and skeleto-muscular systems (under earth conditions) on persons who were submerged in water or had stayed in bed for long times, upon their transfer to a vertical position. This is certainly sufficient to suggest that the same methods and equipment can be applied in space flights, primarily in orbital stations, to counteract the deconditioning effect of weightlessness on the organism.

Undoubtedly, the solution to harmful effects of weightlessness is the introduction of artificial gravity in space ships with human crews. Experiments have shown that an artificial gravity of 0.277 g is quite sufficient to maintain the integrity of all psychological and physiological functions of the human organism during space flights.

Weightlessness is one of the space flight stress factors /52 that will receive particular attention in the furture on the part of space medicine in order to understand the physiological and pathophysiological consequences of its effect on the human organism and to select the most adequate protective measures. Future long-duration space flights will certainly provide more information on the effect of weightlessness on the human organism and will show the limits of human resistance with respect to this non-physiological condition.